



Organization environmental footprint applying a multi-regional input-output analysis: A case study of a wood parquet company in Spain

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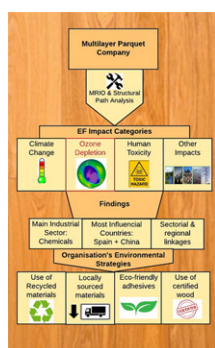
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HIGHLIGHTS

- The organization environmental footprint of a parquet company was proposed.
- Environmental impacts were calculated and the sectorial and regional linkages were identified.
- Spain and China, the chemical sector and indirect impacts were the most influential in the ozone depletion category of this company's footprint.
- Viability and implications of the Environmental Footprint implementation for companies were finally discussed.

GRAPHICAL ABSTRACT



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ABSTRACT

Wood has been presented as a carbon-neutral material capable of significantly contribute to climate change mitigation and has become an appealing option for the building sector. This paper presents the quantification of the organization environmental footprint of a wood parquet company. The multi-regional input-output (MRIO) database EXIOBASE was used with a further structural path analysis decomposition. The application of the proposed method quantifies 14 environmental impacts. Highly influential sectors and regions responsible for these impacts are assessed to propose efficient measures. For the parquet company studied, the highest impact category once normalized was ozone depletion and the dominant sector responsible for this impact was the chemical industry from Spain and China. The structural path decomposition related to ozone loss revealed that the indirect impacts embedded in the supply chain are higher than the direct impacts. It can be concluded that the assessment of the organizational environmental footprint can be carried out applying this well-structured and robust method. Its implementation will enable tracking of the environmental burdens through a company's supply chain at a global scale and provide information for the adoption of environmental strategies.

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1. Introduction

The raising awareness of the environmental performance involved in the building sector has led to the concept of "Green building". This type of building promotes the use of energy-efficient materials and constructive and operational techniques to reduce negative impacts on the environment (Agostino et al., 2017; Bergman and Taylor, 2011; World

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Green Building Council, n.d.). In order to reduce human pressures on the environment and its resources, the construction sector becomes of vital importance. It plays an essential role in Europe's economy, with approximately 3 million companies, 18 million workers and a share of around 9% of the Gross Domestic Product (European Commission, n.d.). Identified as one of the most resource-intensive sectors, the building sector represents 40% of the energy consumption in Europe, of which a large amount corresponds to the manufacturing of building products (Bribián et al., 2011).

In relation to building materials, wood has been presented as a better option when compared to concrete, ceramic, steel and other building materials (Bribián et al., 2011; Cobut et al., 2015; Islam et al., 2015). The fact that wood products have the capacity to store carbon during their service life and delay its return to the atmosphere, evidences their contribution to mitigating greenhouse gas emissions and climate change (Demertzi et al., 2015; Martínez-alonso and Berdasco, 2015). Because of the enormous potential of wood as a renewable, re-usable and recyclable material to contribute positively to Europe's Resource Efficient Roadmap (European Commission, 2011), it is relevant to study the environmental impacts of companies manufacturing wood products.

The Life-Cycle Assessment (LCA) provides a framework suitable for assessing the potential environmental impacts. This methodology has proved to be a well-established tool for measuring the environmental impacts produced by a product or service throughout its lifespan (ISO 14040:2006) and it has been applied in numerous wood-related studies. In relation to wood products, García and Freire (2014) described a life-cycle model for wood-based panels, Min and Guangyao (2014) developed a carbon footprint assessment following an LCA approach for wood furniture, Cobut et al. (2015) analysed the environmental performance of an interior wooden door for non-residential construction and Demertzi et al. (2015) established a LCA for cork floating floors. The three most widely accepted methods proposed for LCA are the process-based method, the input-output method and the hybrid method (Su and Ang, 2014). The majority of the life-cycle assessments performed on individual products apply the process-based method. It is a bottom-up method which considers the activities and operations that may cause environmental pressures (Majeau-Bettez et al., 2011). Despite this method having a high level of detail and accuracy, it presents some disadvantages. Having to collect information for every process involved in a product's life-cycle is time-consuming. It also means having to carry out a high labor intensity work (Suh and Huppes, 2005). Not only implies spending time and effort, but also the most important limitation is the truncation effect due to the difficulty establishing the system boundaries (Alvarez and Rubio, 2015).

To overcome these negative aspects, the Input-Output Analysis method was also proposed for LCA calculations (Chang et al., 2010; Wiedmann et al., 2007). This approach is adequate for industrial sectors, households, individual businesses and average product groups. By applying this method, the direct and indirect emissions produced upstream can be quantified, tracking the impacts throughout the complete production and supply chain (Wiedmann et al., 2011). A more comprehensive approach including the international flows of goods and services can be achieved through MRIO analysis, where inter-industrial and trans-regional human activities are assessed (Budzinski et al., 2017). Given the interest in this approach, investigations have been published applying it to obtain different footprints, for instance the carbon footprint (Tárraro et al., 2017), the nitrogen footprint (Shindo and Yanagawa, 2017), the ecological footprint (Zhang et al., 2017) and the water footprint (Owusu-sekyere et al., 2017). Among all the studied footprints, the carbon footprint has been the most popular for businesses (Berners-Lee et al., 2011; Huang et al., 2009). Major international initiatives, such as the Single Market for Green Products, proposed the organization environmental footprint (OEF) as a useful indicator to quantify environmental impacts (European Commission, 2012; Finkbeiner et al., 2006). What differentiates the OEF from previous footprints is the fact that it evaluates the

environmental stresses from an integrated point of view. Laurent et al. (2012) established the limitations of using a single footprint, such as the carbon footprint, to represent the full environmental impacts. In order to overcome these limitations, the OEF is a multi-criteria indicator that combines around 15 impact categories and provides a more comprehensive approach. Despite the popularity of MRIO analysis, it has not been studied as extensively for the calculation of the Environmental Footprint of organizations.

The aim of this study was to quantify the OEF of a wood parquet business by means of the input-output method. By applying a MRIO analysis and a further structural path decomposition, the total environmental impacts and the linkages between sectors and regions concerning this business were obtained. Further implications of organizations implementing this tool to evaluate their environmental performance are provided.

2. Materials and methods

2.1. Case study

A multilayer parquet company was chosen for the calculation of the OEF applying an input-output approach. Europe's production and consumption of wooden parquet increased from 1990 to 2007. However, with the financial crisis, its production decreased until 2009. From this year onwards parquet's production has experienced a slight recovery, reaching a production of 78.5 million m² in 2015. Among the EU member countries, Spain experienced one of the most significant production gains, increasing its production of parquet 10% in 2015 with respect to the previous year (Global Wood, n.d.).

The company manufactures parquet, which is a wood product for floor covering. The product manufactured by this business is a multilayer parquet consisting of three layers glued together. The first layer located at the top is made of hardwood with a matt lacquer protection. The middle and the final layer, called the backing balancing layer, are aimed at providing stability to the parquet board. The company is located in the Spanish province of Guadalajara and it is a family-owned business founded in 1990. In order to stay competitive in the market, they are studying new measures to improve their public environmental image. The OEF was presented as an indicator to shape their environmental action plans.

Table 1 shows the expenditure data classified according to the 163 industry sectors included in the MRIO database EXIOBASE and used as the final demand vector. It was obtained from the company's accountancy department that provided us with accounting records of the goods and services needed for the processes in Fig. 1 during 2011. Capital expenditure has been considered as direct expenses (executed in the year of study). Consequently, no amortization period has been considered. In the same way, depreciation costs and amortization expenses related to investments from previous years have not been included in the study.

2.2. Methodology

In this paper, MRIO analysis is applied as the methodological basis. This method is capable of quantifying all direct and indirect inputs needed for a specific final demand. Therefore, it is a consumption-based accounting model that shows the interdependencies between regions and sectors within the global economy (Schaffartzik et al., 2014; Turner et al., 2007). Methodological foundations and extensions of Input-Output Analysis can be found in Miller and Blair (2009).

Several MRIO databases have been developed in the past years (Moran and Wood, 2014). In our study, the EXIOBASE 2 MRIO database of 2007, was chosen driven by its highly detailed industrial and environmental information compared to other databases (Wood et al., 2015). Coming from the initiative Compiling and Refining Environmental and Economic Accounts (CREEA), EXIOBASE 2 contains tables for 27 EU

Table 1
Economic inputs involved in the multilayer parquet company.

Sectors	Inputs (€)
Manufacture of machinery and equipment n.e.c.	837,176
Manufacture of fabricated metal products, except machinery and equipment	40,893
Paper	12,451
Manufacture of rubber and plastic products	5749
Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessories	49,491
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	1452
Construction	8847
Chemicals n.e.c.	97,746
Petroleum refinery	30
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	145
Production of electricity by coal	3787
Production of electricity by gas	2791
Production of electricity by nuclear	3943
Production of electricity by hydro	1148
Production of electricity by wind	1148
Production of electricity by biomass and waste	1796
Production of electricity by solar photovoltaic	1148
Production of electricity by solar thermal	1148
Production of electricity by tide, wave, ocean	1148
Production of electricity by Geothermal	1148
Production of electricity n.e.c.	312
Renting of machinery and equipment without operator and of personal and household goods	107,903
Post and telecommunications	9960
Education	6400
Publishing, printing and reproduction of recorded media	881
Financial intermediation, except insurance and pension funding	52,965
Real estate activities	35,712
Other land transport	18,247
Air transport	4969
Sea and coastal water transport	6247
Public administration and defense; compulsory social security	166,305
Processing of food products n.e.c.	3039
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	673,490

n.e.c.: not elsewhere classified.

countries, 16 major economies and 5 rest of world regions in industry by industry (163 sectors) as well as product by product (200 products) classification.

When the objective is to measure the environmental burdens associated with these trades and interactions, the Environmentally Extended Input-Output Analysis (EEIOA) has proved to be a suitable approach (Dias et al., 2014; Piñero et al., 2015; Rocco and Colombo, 2016). Economic flows are transformed into physical flows by means of an environmental intervention matrix (e). It is assumed that the impacts related to an industry are generated with the same intensity (Miller and Blair, 2009).

The basic IOA modeling equation that has traditionally been applied to calculate economic impacts and can be expressed as:

$$X = (I - A)^{-1} Y \quad (1)$$

The variables in this expression can be vectors or matrices. In our case, the matrix form will be used hereafter. X is the total output matrix and Y the final demand vector which once diagonalized becomes a matrix. $(I - A)^{-1}$ is known as the Leontief inverse matrix (L). I is the identity matrix and A is the technical coefficient matrix. The Leontief inverse matrix consists of multipliers that depict the production of each industry in order to meet the final demand.

In order to obtain information regarding environmental aspects, a specific vector containing the pollution generated by industrial sectors and regions is required. This vector is the environmental intervention vector (e) containing the environmental burdens per monetary unit of

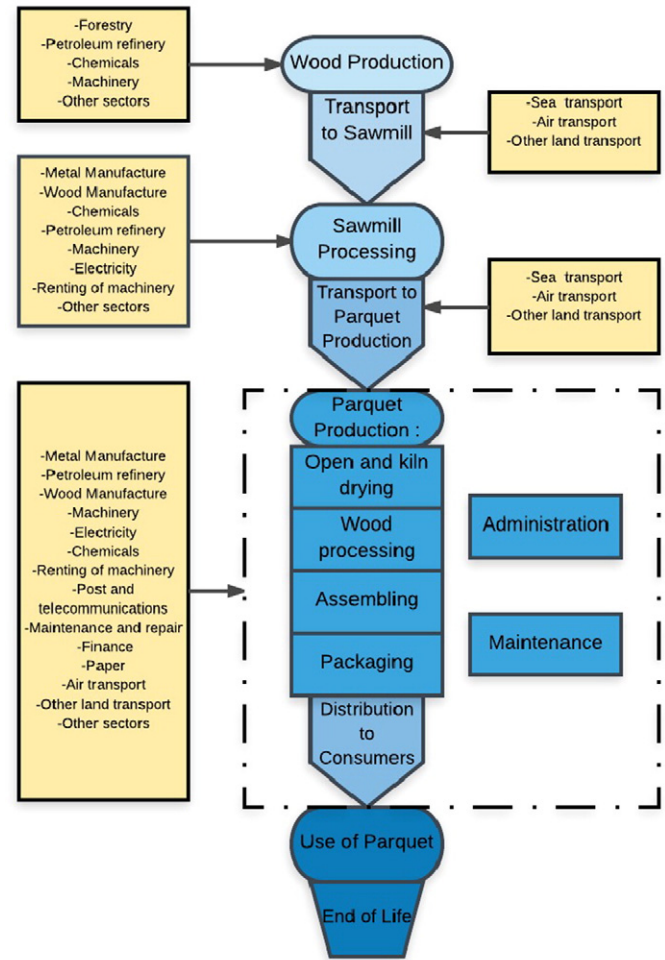


Fig. 1. Activities of the multilayer wood parquet. The dotted box indicates the boundaries of the parquet company.

each sector and region. Process-based coefficients from a robust and quality-assured life-cycle method, the ILCD midpoint, was used to create this matrix e (JRC European commission, 2011). By including this diagonalized vector in expression (1), the total impact (E) can be calculated. The final equation obtained for the EEIOA and applied in this paper is:

$$E = e(I - A)^{-1} y \quad (2)$$

There are two points of view concerning the total impacts. By summing the rows of the matrix E , the total impacts are obtained from the producer's perspective, known as the country's producer responsibility. By summing the columns of the matrix E , the total impacts are identified as the consumer's responsibility and it is related to the total, direct and indirect, impacts generated worldwide as a result of a final demand. The latter is adopted in this paper to measure the OEF formed by 14 impact categories. The ionizing radiation was excluded due to the lack of data in EXIOBASE 2 database. Once the total impacts for each category were calculated, the results were then normalized with the domestic normalization factors per person for EU-27 provided by the European Commission (Benini et al., 2014) and expressed per m² of parquet.

By applying Eq. (2), the total environmental impacts are obtained. A further decomposition of the Leontief inverse (L) using a power series expansion allows the calculation of the direct and indirect multipliers

(de la Rua and Lechon, 2016; Zafrilla et al., 2014). The decomposition of the L is as follows:

$$L = (I - A)^{-1} = (I + A + A^2 + A^3 + \dots + A^n) \quad (3)$$

The direct multipliers (LD) and indirect multipliers (LI) are expressed as shown in Eqs. (4) and (5). See that indirect multipliers can, in turn, be divided in individual summands.

$$LD = (I) \quad (4)$$

$$LI = (A + A^2 + A^3 + \dots + A^n) \quad (5)$$

Once the results are normalized, the most influential impact category is chosen to conduct a structural path analysis. In order to do so, the final demand is divided into six vectors: adhesives, machinery, transport, sawn wood, electricity and other sectors. Including the multipliers in Eqs. (4) and (5) in Eq. (2), the direct and indirect environmental effects of the six final demands are obtained.

$$ED = eIY \quad (6)$$

$$EI = e(A + A^2 + A^3 + \dots + A^n)Y \quad (7)$$

Eq. (6) expresses the direct environmental impacts (ED) and Eq. (7) the indirect environmental impacts (ID), and Y in both equations is the six final demands. Therefore, the structural path analysis results will provide the distribution of direct and indirect impacts according to the sectors involved. These impacts are expressed as the total environmental impact divided by the total amount of functional units produced, in this particular case g CFC-11 eq/m². In order to identify the main sectors, results have been expressed as the intensity, which is the unit of the impact category per euro (g CFC-11 eq/€).

3. Results

3.1. Total organization environmental footprint

Table 1 presents the economic inputs involved in the multilayer parquet studied and used as final demand in our MRIO model. There are several industrial sectors that present high values. The highest expenses are found in the sectors “Manufacture of machinery” and “Renting of machinery”. These expenses are justified because many processes in the manufacturing of timber, such as sawing and drying, are highly mechanized. Another relevant sector is “Chemicals”, where money is spent in glues and lacquers used for the assembly and finishing of the product. Finally, as expected, the industrial category “Manufacture of wood” can also be highlighted for having a high expenditure, 31% of the overall economic inputs.

Considering the above-mentioned financial data, Table 2 summarizes the total OEF obtained for each of the 14 impact categories. These findings revealed that the impact of climate change for this company was a 16% higher than the obtained by a German multilayer parquet industry (Nebel et al., 2006). The big difference obtained for the climate change impact could be partly due to using different methods. It has been documented that results obtained with the process-based method, which was used by the German industry, are lower than those obtained applying the MRIO analysis (Majeau-Bettez et al., 2011). In comparison with the manufacturing of a floating floor, the multilayer parquet studied exhibited higher environmental emissions in the categories climate change and ozone depletion. On the other hand, similar results were registered for the rest of the impact categories, with the exception of human toxicity cancer effects, which was a 68% lower for the parquet compared to the floating floor (Demertzi et al., 2015). When compared to other wood flooring products, the challenge identified for this

Table 2

Total and normalized impacts per m² corresponding to the EF impact categories of the multilayer parquet company.

Impact category	Unit	Impacts	
		Total	Normalized
Climate change	kg CO ₂ eq/m ²	1.52E+01	1.65E−03
Ozone depletion	kg CFC-11 eq/m ²	2.31E−02	1.07E+00
Human toxicity cancer effects	CTUh/m ²	6.09E−08	1.65E−03
Human toxicity non-cancer effects	CTUh/m ²	4.44E−06	8.33E−03
Acidification	molc H ⁺ eq/m ²	1.37E−01	2.89E−03
Particulate matter	kg PM 2.5 eq/m ²	9.33E−03	2.45E−03
Ecotoxicity-freshwater	CTUe/m ²	2.89E+00	3.30E−04
Photochemical ozone formation	kg NMVOC eq/m ²	6.84E−02	2.16E−03
Eutrophication-terrestrial	mol N eq/m ²	2.47E−01	1.40E−03
Eutrophication-freshwater	kg P eq/m ²	1.54E−03	1.04E−03
Eutrophication-marine	kg N eq/m ²	2.19E−02	1.29E−03
Land use	kg C deficit/m ²	5.61E+02	7.51E−03
Resource depletion-water	m ³ water eq/m ²	4.17E−01	5.12E−03
Resource depletion-mineral & fossil	kg Sb eq/m ²	1.58E−04	1.56E−03

company is to implement changes in the parquet manufacturing that will result in a reduction of the climate change and ozone depletion impacts to improve its product environmental performance.

Each impact category is expressed in their own units. Therefore, to enable comparison between them, these results were then normalized (Table 2). After normalization, it was concluded that ozone depletion is the impact category that played the most important role in the company's environmental footprint. At a global scale, the use of ozone-depleting substances, such as chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) and to a less extent hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs) are being controlled and reduced. However, the European Union's emissions of CFCs for 2013 were 16 t, close to the limit imposed by the Montreal Protocol of 17 t (European Environment Agency, 2013). In Spain, as well as in Europe, policies were implemented to control and forbid the use of certain chemicals which damaged the ozone layer. Currently, in this country, the use of CFCs are only allowed for pharmaceutical purposes. The downside is that the substances like HFCs and PFCs, used as substitutes, present a high greenhouse effect. The Spanish inventory for gas emissions in 2016, registered a total of 9318.2 kt CO₂ eq of HFCs and 87.5 kt CO₂ eq of PFCs, which represent 3% of the overall emissions to the atmosphere. Despite using substitutes of strong ozone-depleting substances in Spain, the so-called weak chemicals increase this country's climate change impact (MAPAMA, 2016). Initiatives that claim greener alternatives have been proposed. Some companies have already implemented the use of natural chemicals and technologies in their manufacturing processes (Greenpeace, 2004). Following this direction, this Spanish company could study these alternatives and include them in their future action plans. Related to the wood industry, Demertzi et al. (2015) reported that the large amount of chemicals used in the manufacturing and painting processes involved in wood flooring production is an important contributor to ozone depletion. As well as the use of resins and varnishes, the sawmill process is recognized to be an energy-intensive process contributing to increasing the impact category climate change. Furthermore, these greenhouse gas emissions also affect the depletion of the ozone layer by creating conditions that lead to ozone loss (Björn, 2017). As ozone depletion was identified to be by far the most significant contributor to this organization's EF, the following analyses were carried out considering this impact category.

3.2. Detailed organization environmental footprint related to ozone depletion

A main strength of the MRIO approach is the identification and location of the sectors that contribute to the overall impact categories. Fig. 2 provides a clear representation of the intensity each industrial sector has on the impact category ozone depletion. The bigger the sector area in the treemap, the higher the environmental intensity. It can be



Fig. 2. Ozone depletion intensity (g CFC-11 eq/€) per industrial sector of the multilayer parquet.

noted that “Chemicals” presents the highest intensity, which is 641 g CFC-11 eq/€ and stands for the 85% of the total ozone depletion impact. The other significant sectors are “Manufacture of wood” and “Manufacture of machinery”, accounting for 38 g CFC-11 eq/€ and 31 g CFC-11 eq/€, respectively. As mentioned in the section above, the usage of chemicals, wood and machinery are essential for the manufacture of multilayer parquets and the expenditure in these sectors is higher. To some extent, higher expenses are related to higher environmental pressures (PriceWaterhouseCoopers, 2009). However, some sectors are characterized by their high environmental intensity, such as the chemical sector (Zhao et al., 2017). In this case, the chemical sector, despite having less expenditure than the manufacture of wood and machinery sectors, presents the highest environmental intensity.

This type of analysis reveals the sectorial hotspots in the production of parquet concerning ozone depletion and can contribute to shaping more sustainable consumption and production patterns. A step in this direction could be to promote the use of environmentally friendly chemicals, which are labeled as eco-friendly, nontoxic, safe and natural and that are available in the market (Yuan et al., 2017). Companies, as the one presented in this paper, could be willing to use substitutes for harmful chemicals currently present in their manufacturing process. A future measure to be implemented in the short-term by this business is to purchase from suppliers adhesives that certify low-formaldehyde emissions and phenolic-based resins. Another measure to take into account in the production processes could be to try and minimize the impacts generated by machinery. These impacts are closely related to the energy consumed and greenhouse emissions generated. Reductions in the energy consumption could be achieved by improving and upgrading existing manufacturing technologies. In addition, it was also reported that optimising the processes of wood manufacture could result in lower emissions (Martínez-alonso and Berdasco, 2015). However, this small business is less capitalized and in order to maximize the profit, less quality machinery was purchased. The next step they are considering for the mid-term is to upgrade the existing machinery to improve the wood recovery and reduce emissions. In relation to the wood, which is the main resource used in this parquet's manufacturing company, it should be noted that both well-extended certifications (FSC and PEFC) are currently used. Although illegal wood is cheaper to acquire, because no environmental policies are followed, this company has decided to provide added value to their environmental performance and public image.

Furthermore, applying a MRIO model instead of a mono-regional model has the advantage of addressing the environmental impacts from a global perspective. MRIO is capable of tracking the regions and industrial sectors in which the impacts occur. Fig. 3 summarizes the global linkages involved in the studied company. This kind of diagram represents the links between sectors and countries generating the impacts. The color and size of the flows are useful in order to spot which sector and country are generating the highest impacts. At first sight, it can be seen the high contribution of Spain and China to the depletion of ozone generated by the company of parquet. The Spanish intensity contributes a 48% of the total ozone depletion, followed by China with a 25%. In comparison with these two countries, the rest of the countries included sum up to 27%. Multilayer parquet production relies on several industrial sectors with massive regional ramifications. The dominant sector related to the studied impact category is “Chemicals” with a weight of 85%. A total amount of 641 g CFC-11 eq/€ was due to this industrial sector, from which 46% corresponds to Spain and 30% to China. Another important contributor is the sector “Manufacture of wood”. Whereas two clear regions could be identified in the chemicals sector, in the wood sector more countries influence it. Its main countries contributing are Finland, France and Portugal, with a 27%, 21% and 12%, respectively. The last significant sector is “Manufacture of machinery”. Spain represents a 13% of the overall intensity related to the machinery sector, while Slovenia can be identified as a very emission intensive country, as it contributes with a 75% of the total intensity for this sector.

4. Discussion

Modeling the interdependencies between sectors and world regions is a useful analysis that provides a more in-depth study of the product's impacts (Zafrilla et al., 2014). In this sense, information related to the origin of the impacts across the supply chain can be extracted from this method. In the organization studied in this paper, China appeared to have a dominant role in the impact category ozone depletion. In spite of the fact that the multilayer parquet's production does not demand any goods or services directly from China, results show that this country has a dominant role indirectly in the chemicals sector. On this basis, care has to be put in all the agents involved through the entire supply chain, even the indirect ones, in order to implement green supply chain management practices (Li et al., 2016; Walker et al., 2008). Additionally, environmental legislation differs depending on the regions and so, the

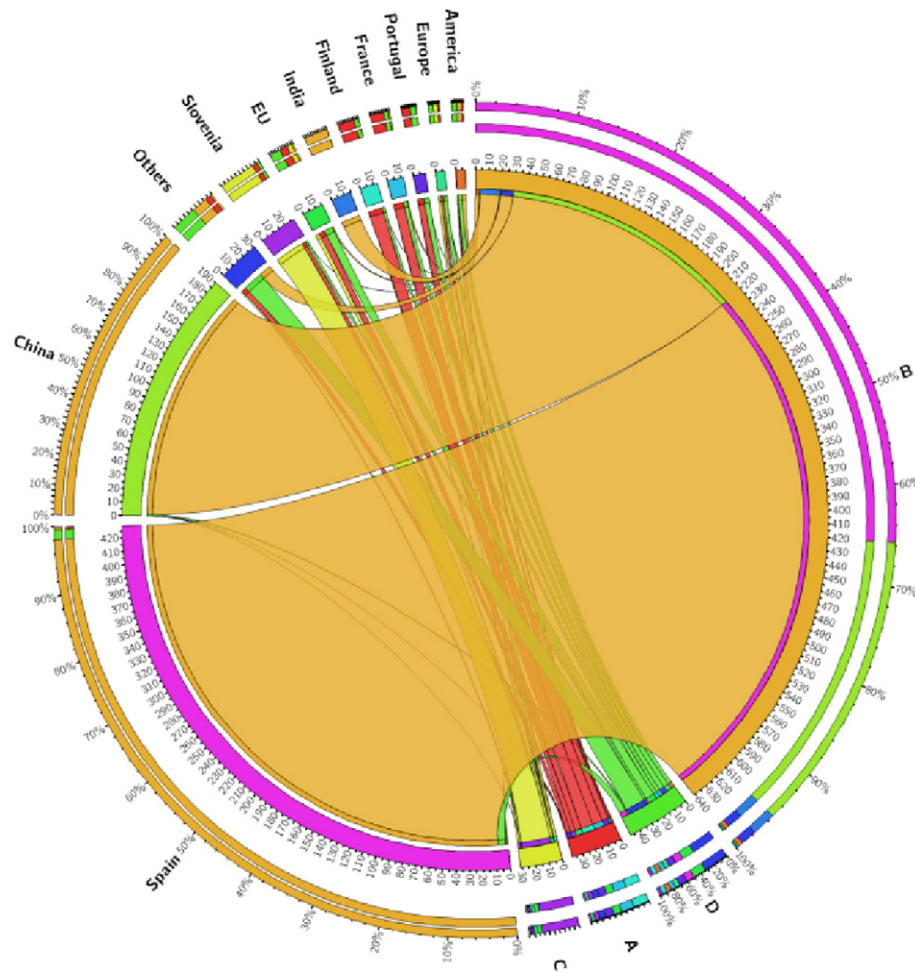


Fig. 3. Ozone depletion linkages (g CFC-11 eq/m²) by sectors and countries involved in the wood parquet production. Sectors: A. Manufacture of wood; B. Chemicals; C. Manufacture of machinery; D. Other sectors. Countries: Spain; Finland; France; Portugal; Slovenia; China; India; EU (rest of the European Union countries); Europe (rest of countries in Europe not belonging to the European Union); America (United States, Canada, Brazil) and Others (rest of the world).

goods and services imported, directly or indirectly, from these countries could result in higher impacts (McCullough, 2017). Two approaches companies could adopt could be de-selecting suppliers not meeting environmental standards and through inter-organizational management (Kogg and Mont, 2012). The first approach is less effective, as the de-selected supplier could be delivering to other companies instead. On the other hand, requesting suppliers to report their compliance with environmental laws is more effective in order to reduce indirect impacts (Kjaer et al., 2015). The parquet company could demand environmental documentation to suppliers to try and implement a greener supply chain, starting by choosing adequate chemical suppliers as it is the most influential sector.

Driven by the “Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan”, the European Commission is heading towards the improvement of organizations’ environmental performance. A range of policies has been included to boost resource efficient and eco-friendly products and raise awareness among final consumers (European Commission, 2008). The MRIO model allows a comprehensive assessment to obtain environmental information. Its implementation will benefit the communication of the environmental performance of products, better-informed purchasing decisions will be taken by consumers and the initiative of Single Market for Green Products will be reinforced (European Commission, 2013). Following the method presented here, using a MRIO model and the structural path analysis, the direct and indirect impacts involved in an organization’s supply chain can be obtained. For the Spanish parquet company investigated, the direct impacts concerning ozone depletion were

11.01 g CFC-11/m². A similar result was obtained for the indirect impacts, which were 12.14 g CFC-11/m². Although the impacts generated from the direct demand for goods and services and the impacts embedded upstream the supply chain were approximately the same, the distribution per sector differed (Fig. 4). The dominant contributor in the impacts of ozone loss was the chemical sector, accounting for 46% for direct impacts and 51% for indirect impacts. For transport and electricity the main source of the impact was also identified in the supply chain, while machinery and wood impacts produced directly are higher than indirect emissions.

This type of information is necessary to encourage eco-innovation and design new strategies to reduce the OEF. In the case proposed, alternatives that imply fewer impacts could be studied. An example could be to use locally sourced materials. That way the transport distances would be reduced and fewer emissions would be generated. The utilization of recycled materials could also be an alternative to reduce the parquet’s footprint. The inclusion of materials that are discharged during the different manufacture processes has numerous benefits, from reducing the amount of waste to landfills to reducing carbon emissions to produce the new materials (Wang et al., 2016).

Environmental monitoring indicators, such as the OEF, can be used as the basis for environmental regulations. The input-output method can provide sector-specific information to measure the environmental performance of global supply chains (Acquaye et al., 2016). In addition, it can serve as a useful tool for businesses to establish their environmental strategies (Huang et al., 2009). From the organizational point of view, companies are facing the challenge of having to comply with strict

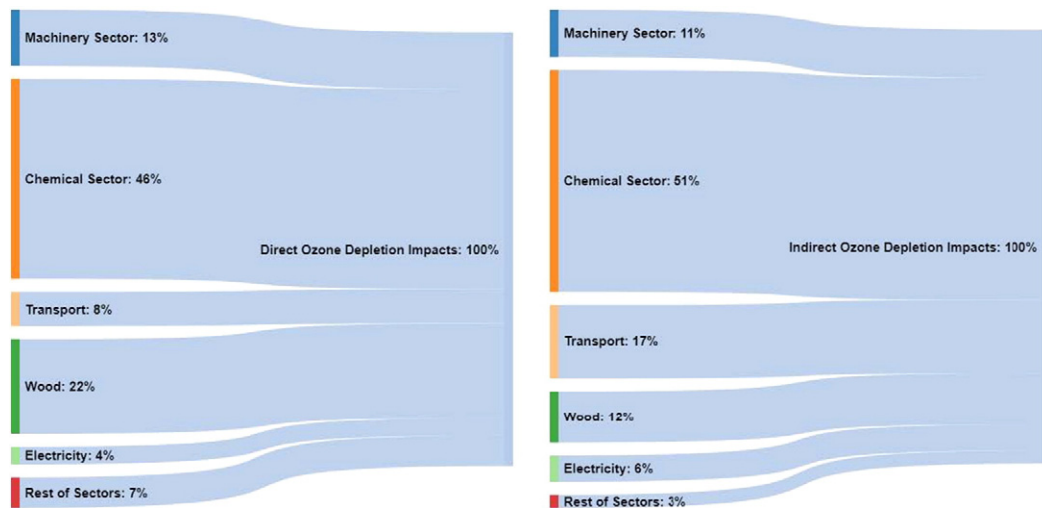


Fig. 4. Distribution of the direct and indirect ozone depletion impacts per sectors of the Spanish parquet company.

environmental policies and at the same time, they need to stay competitive in the market. As a consequence, a growing interest in eco-innovation and greener production has emerged from companies willing to offer sustainable products (Dechezleprêtre and Sato, 2017; Zhao and Sun, 2016). The first step needed to adopt sustainable consumption and production patterns is to carry out an LCA of the product following the guidelines of the ISO 14040 and the ISO 14044. However, the reality when facing the calculation of its footprint is that organizations are looking for cost-effective, time-saving and easy-to-use tools which provide reliable results. In agreement with the conclusions of previous authors, the MRIO approach is recognized to follow a robust methodology relying on the full supply chain and being less data-intensive compared to other methods (Li et al., 2017; Lutter et al., 2016; Su and Ang, 2014).

The method presented in this work and applied to our case study provides a good basis for the calculation of the OEF. EXIOBASE 2 database has been specifically developed for environmental applications and provides a high level of detail in emission flows (Tukker et al., 2016). The environmental extensions include 85 different types of emissions, divided into soil, water and air, which are described in the CREEA reports (Wood et al., 2013). The significant amount of environmental elements considered increases the validity of the results. However, uncertainty due to time-validity has to be taken into account, as the MRIO data is based on 2007 and the economic data for this study is from 2011. Additionally, more accurate results could be obtained if MRIO databases were elaborated with greater sectorial and regional detail. Bouwmeester and Oosterhaven (2013) investigated the errors associated with sectorial and spatial aggregations. Findings showed that for some impact categories, such as climate change, a certain level of aggregation is acceptable, while in other cases, as water use, the impacts are underestimated. It is expected that future efforts will improve these limitations, such as the EXIOBASE 3 database developed by the Desire project. In the same way as the development of this database, the availability of more MRIO tables will provide valuable tools for a range of environmental economic assessments (Owen et al., 2017; Reutter et al., 2017; Tukker et al., 2012).

5. Conclusions

In the present paper, the OEF of a multilayer parquet company applying a MRIO and structural path analyses is proposed. These approaches have proved to be a transparent and applicable method to evaluate a company's environmental performance. It is suited to obtain the environmental impacts and intensities of a business and spot the location of these impacts across its supply chain. For the multilayer parquet company studied here, the highest impact category was ozone

depletion and the dominant sector responsible for this impact was the chemical industry from Spain and China. In relation to the structural path decomposition, results showed that the indirect impacts were slightly higher than the direct impacts. The assessment carried out evidences this tool is able to quantify the OEF. Despite the limitations due to temporary differences and sectorial and spatial aggregations in the use of MRIO tables, it would be beneficial for firms to make use of them in order to shape their action plans based on sustainability. To be at the forefront of environmental innovation is important to become familiar with eco-design, eco-consumption and eco-production. The consideration of the OEF under this approach will pave the way to prompt greener economies, supported by policymakers and environmental legislation, and ensure a resource-efficient management of the ecosystem goods and services.

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